Final Report
for FY 1995 funding of the
cooperative agreement entitled
generation and conservation of design knowledge

Generation and Conservation of Design Knowledge

a notebook environment for design experience reuse

FINAL REPORT

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attention
University Affairs

by
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ABSTRACT

This final report is being submitted for the collaborative agreement entitled Generation and Conservation of Design Knowledge (GCDK). During FY95 the following milestones were achieved.

Work Completed in FY95:

1. Conducted tests to integrate Dedal 2.0 with WAIS.
2. Deployed Dedal to support documentation of Gravitational Biological Facility project.
3. Developed an information theoretic GCDK design process model.
4. Supported Dedal commercialization by EIT (SBIR contractor Phase II).
5. Publications for FY95:

   1. Viste, M.J., Cannon, D.M., "Firmware Design Capture", in the Proceedings of the 1995 ASME Design Theory and Methodology Conference, Boston, MA, Sept. 18-20, 1995.

   2. Mabogunje, A., Leifer, L., Baudin, C., Levitt, R., "ME210-VDT: A Managerial Framework for Measuring and Improving Design Process Performance", in Proceedings of Frontiers in Education Conference, Atlanta, GA, November, 1995.

   3. Baya, V. , Leifer, L., "Understanding Information Handling Behavior Using Time and Design Information Measure", in the Proceedings of the 1995 ASME Design Theory and Methodology Conference, Boston, MA, Sept. 18-20, 1995.

   4. Brereton, M., Sheppard, S., Leifer, L., "How Students Connect Engineering Fundamentals to Hardware Design: Observations and Implications for the Design of Curriculum and Assessment Methods", in Proceedings of the 1995 International Conference on Engineering Design, Prague,August 22-24, 1995.

   5. Hong, J., Leifer, L., "A Hypertext Design Notebook", in Proceedings of the 1995 International Conference on Engineering Design, Prague,August 22-24, 1995.

   6. Hong, J., Toye, G., Leifer, L., "PENS: Personal Electronic Notebook with Sharing", submitted to the fourth IEEE Workshop on Enabling Technologies, Berkeley Springs, West Virginia, April 20-22, 1995..

6. Workshop presentation & paper FY95:

   1. Cannon, D.M. and Leifer,L.J., "Engineering Practice as both Laboratory and Target for Design Research", 1995 Joint ASME/JSME Workshop on Developing and Implementing Design Technologies, Boston, MA, Sept. 17, 1995.

Ongoing work to be carried over from FY95 to FY96:

7. Integrate Dedal with ICM to automatically extract device model from graphical representation of 3D models in ICM.
8. Develop an automatic Indexing Scheme for Dedal.

Related Contributions:

We continued validation of the approach and strategic objectives of our original proposal; to study NASA mission design tasks in context, develop computational support tools and protocols that help NASA engineers, scientists, administrators and contractors create (generate) design knowledge while conserving and indexing it for REUSE. In the last year, our focus was on making Dedal easier to use and handing off the prototype version to Enterprise Integration Technologies (EIT) for commercialization. The commercial version of Dedal has been named "Web Librarian" and its Alpha version was used on the ARPA MADEFAST project, a major test of GCDK concepts in the context of an ARPA sponsored knowledge sharing experiment in which seven universities and three corporations formed a virtual enterprise to design and manufacture a functional "IR Seeker" in six months[1].

The GCDK team and the content of last year's statement-of-work (SoW) made a continuing contribution to the SHARE and MADEFAST consortia on concurrent engineering. SHARE (a scalable methodology and framework for concurrent engineering) is ARPA funded and jointly directed by Professors Leifer and Cutkosky in Collaboration with EIT corporation (Marty Tenenbaum). The leading participants of MADEFAST experiment were Stanford University, Enterprise Integration Technologies (EIT) and the University of Utah. Others include CMU Engineering Design Research Center, Lockheed Artificial Intelligence Center, MIT Artificial Intelligence Laboratory, MSU Intelligent Systems Laboratory (ISL), Texas A&M Computer Aided Manufacturing Laboratory [ref: http:// cdr.stanford.edu /html /MADEFAST/ participants.html].

The follow-on project to SHARE is titled Design Space Colonization (DSC) and is closely linked to coordinate efforts in the Palo Alto Collaborative Concurrent Engineering Environment (PACE) consortium. GCDK makes NASA a key element in this group.

Professor Leifer is also co-principal-investigator with Professor Sheri Sheppard on the NSF sponsored National Engineering Education Synthesis Coalition. Consortia members include: Cornell University, Hampton University, Tuskegee University, Southern University, Cal Poly San Luis Obispo, University of California at Berkeley and Stanford University. The coalition is charged with revolutionizing undergraduate education. Mechatronics is a curriculum revision focus for the coalition. Engineering education "capture and reuse" is a central theme in the Synthesis approach to teaching and learning (a lesson learned from the NASA-GCDK project). In fact there is great synergy between the following two questions, one specifically germane to NASA and the other germane to engineering education and NASA generally:

1. How do aerospace engineers do design and how are they best supported by computational tools and services ?

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1. Kholsa, P., Collaborative Design, invited speaker at the 1995 International Mechanical Engineering Conference and Exposition, San Francisco, CA, November 12-17, 1995

2. How do engineering students learn engineering and how are they best supported by computational tools and services ?

Collateral associations like these assure wide spread dissemination of NASA sponsored research and assure that the work itself is well informed by the activity of others.

Core Research Accomplishments:

The core objective of this project was to capture, represent, formalize and assess the reuse of design knowledge in the context of aerospace design [Figure 1]. We tested the hypothesis that, design knowledge conservation (capture, representation, reasoning and retrieval) will be far less costly than re-invention of comparable knowledge. We developed and refined the concept of an electronic engineering design notebook paradigm as a unifying metaphor for concurrent aerospace engineering design.

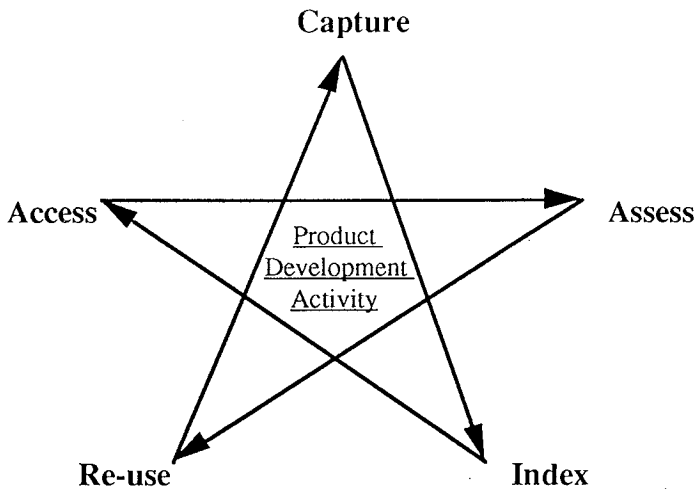

Figure 1. Tools and services that we contribute to design have the development of real products as the central, unifying activity. The *capture* and *indexing* of design work are supported by such computer tools as PENS and Dedal. These tools give engineers *access* to this work, and allow us to *assess* the value of this support as engineers *re-use* information in their ongoing design work. This cooperative cycle is only possible through a close association between researchers and practicing engineers.

Product Development Activity:

Deep involvement with real design activity in parallel with the research program has been a core strategy in the GCDK NASA-Stanford cooperative agreement. This approach kept the research grounded in reality through constant feedback from designers.

In our work with NASA, we have demonstrated the effectiveness of Dedal's indexing and retrieval schemes (by means of tests on the Continuously Variable Damper domain) and the ability of Dedal to support indexing, modeling and retrieval in real time (by means of supporting the NASA-ARC Bioreactor project over two design cycles). We successfully ported Dedal to the Macintosh Platform so that a larger percent of NASA engineers and scientists can readily access and use Dedal. We supported the use of Micro-Dedal (the Macintosh version of Dedal) in the Gravitational Biological Facility (GBF) Project, and

also supported the conversion of Dedal to a World Wide Web (WWW) service called Web-Librarian.

In FY'95, we supported the JPL sponsored Pico Satellite project. This was be our first opportunity to support a redesign task using tools and services that are uniformly distributed among Stanford , NASA-Ames, and JPL sites.

Design Information Capture:

An important outcome of our collaboration on the ARPA sponsored SHARE/MADEFAST/ME210 program was the development of PENS (Personal Electronic Notebook with Sharing). This Macintosh based software supports personal note taking and sketching and goes a long way in facilitating communication between design team members.

Design Information Indexing

Design information segments are indexed in Dedal by being assigned a topic and an argument. The topic and the argument combination form a question, the answer to which can be found in the segment. The choice of topics was derived from experiments performed in the summer of 1991 and further validated in 1993. One of Dedal's innovative contributions is the use of a design-artifact device model to facilitate answer retrieval. The model is intentionally simple and composed mainly of "PART-OF" and "IS-A" hierarchy elements that describe the structure of the device. The simplicity of the model is a requirement as it must be created in real-time by the design team itself as the project progresses and changes.